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THE EMERGING PHOTOVOLTAIC INDUSTRY: AN ANALYSIS OF LITERATURE ON INTERNATIONAL MARKETS AND TRENDS

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PREPARED BY:

Peat Marwick Consulting Group
112 Kent Street, 21st Floor
Ottawa, Ont.
K1P 5P2
(613) 237-2120

SCIENTIFIC AUTHORITY:

Jack Cole
Efficiency and Alternative Energy Technology Branch
Energy, Mines and Resources Canada
580 Booth Street
Ottawa, Ont.
K1A 0E4

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The above review of public sector involvement in the various countries indicate that Europe and Japan have a firmer commitment to PV than Canada and the U.S. The U.S. private sector is, however, very independent and seems quite strong.

SUMMARY

It is concluded from the literature review that PV module and installed systems costs will be considerably lower by the year 2000. By that time, given its natural advantages of safety and no pollution, PV technology will be widely adopted for telecommunications, telemetry, cathodic protection, pumping, rural off-the-grid and diesel replacement applications.

The worldwide markets for PV systems are encouraging. The developing nations in South Asia offer tremendous opportunities.

Amorphous silicon technology-related breakthroughs are expected in U.S., Europe and Japan. Europe and Japan have additional joint interests in polysilicon crystals. Government support for PV has wavered in most countries except Europe and Japan.

The literature review indicates that a strategic vision of energy policy is necessary both in the U.S. and in Canada. The U.S. industry has shown that it can survive despite the withdrawal of tax credits. The Canadian industry, however, is too small to sustain itself and may need government support. This, and related issues, will be addressed through our survey of the companies comprising the Canadian industry.

RÉSUMÉ

Après examen des documents, il est possible de conclure que le coûts des modules photovoltaïques et des systèmes installés diminuera considérablement d'ici l'an 2000. D'ici là, compte tenu des avantages naturels, tels la sécurité et l'absence de pollution, la technologie photovoltaïque prendra de l'essor dans les domaines des télécommunications, de la télémétrie, de la protection cathodique, des pompes, de la production d'électricité en milieu rural ou dans un milieu non desservi par un réseau, ainsi que du remplacement de génératrices diesel.

Les perspectives sont prometteuses pour les systèmes PV sur les marchés mondiaux. Les pays en voie de développement du sud de l'Asie offrent des possibilités immenses.

On s'attend à des percées dans le domaine de la technologie connexe au silicium amorphe aux États-Unis, en Europe et au Japon. L'Europe et le Japon ont, par ailleurs, des intérêts communs dans les cristaux de polysilicium. L'appui des gouvernements envers l'énergie photovoltaïque a diminué dans la plupart des pays sauf en Europe et au Japon.

L'examen des documents indique qu'une vision stratégique de la politique énergétique est nécessaire tant aux États-Unis qu'au Canada. L'industrie américaine a démontré qu'elle peut survivre en dépit de l'élimination des avantages fiscaux. L'industrie canadienne, cependant, est de trop faible dimension pour pouvoir s'autosuffire et pourrait nécessiter une aide du gouvernement. Cette question, ainsi que d'autres questions connexes, seront examinées plus en profondeur grâce à notre sondage sur les entreprises au sein de l'industrie canadienne.

The Emerging Photovoltaic Industry - An Analysis of International Markets and Trends

Introduction

The photovoltaic industry has gained prominence throughout the world. Technological advances during the past 10 to 15 years have made many more applications of photovoltaic cells feasible and cost competitive. Today, at least 500 companies in the world are engaged in some activity related to photovoltaic research, manufacturing, system integration and marketing.[1]

This is a brief review of the relevant and recent literature on the international photovoltaic market. Its major focus is on trends relating to: technology and price; market developments and size; and public sector policy. Since the bulk of the literature reviewed originated in the U.S.(most non-U.S. literature is either unavailable or not in English) the trends reported in this review primarily reflect the thinking of U.S. specialists on the worldwide photovoltaic markets.

Method

The literature review was conducted in several stages. First, a long list of relevant literature was discussed with experts in our stage 1 survey to identify the key literature. Also, our expert advisor, Don Adkinson, provided some critical inputs. Secondly, an attempt was made to obtain the key reports and articles from libraries in U.S. and Canada. Some critical reports which were not available on inter-library loan were purchased. Lastly, the selected reports and articles were examined for the purposes of identifying market trends and comparing the various forecasts. This review presents the most significant market trends and those market forecasts which, in our opinion, appear to reflect the demand for PV most accurately compared to other forecasts.

1 M.J. Blanco, **Photovoltaic Export Trade of the U.S.A.**, Solar Trade International, 1987.

A reference list of the literature reviewed and a complete bibliography of sources identified are provided as **Appendix A** and **Appendix B**, respectively.

Technology and Price Trends

Currently, there are five key types of photovoltaic systems in which silicon is the principal energy conversion material used. These are called single crystal silicon, poly-crystalline silicon (cast ingot), ribbon/sheet, concentrators, and amorphous silicon-based modules.

The **single crystal** growing techniques which are in use produce the highest efficiency cells. The **poly-crystalline** silicon cells are approaching the efficiency of single crystal cells and also have excellent lifetimes. More research is being undertaken to produce better poly-crystalline silicon cells. The most efficient method of producing silicon cells involves the spraying of thin films of **amorphous silicon** on a substrate. With respect to amorphous silicon, more research is needed to prevent the photo current from recombining on impurities. The **concentrators** which optically focus sunlight onto a small area are very popular in strong sunlight areas such as the Southwestern U.S. The **silicon ribbon sheet** is in pilot promotion at Westinghouse and Mobil. Of the above technologies, more and more research is concentrated on amorphous silicon.

U.S., Europe and Japan are all involved in research pertaining to amorphous silicon. It is estimated that nearly two-thirds of professional talents in PV research are directed toward improving amorphous silicon producing methods.[2] The technologies used by the various U.S. manufacturers are shown in **Exhibit 1**[3]. Despite the emphasis on amorphous silicon research, there is a strong indication that the European firms will continue to work on polycrystal and single crystal cells. Wacker and Siemens lead this field and have a joint venture with Kyocera in Japan.

The research into high purity silicon is closely related to the long-run viability of the photovoltaic industry. It is hoped that research will lead to reduced silicon wafer costs, greater efficiencies in the conversion of sunlight to electricity, advances in the state-of-the-art cell and lower production costs. Increased efficiencies together with lower production costs are critical factors in lowering the market competitiveness of PV systems.

2 Frost and Sullivan, **Photovoltaic Market in the U.S.**, July 1985.
3 All exhibits are presented at the end of this review.

Maycock[4] summarizes the various factors which will lead to cost reductions. These are:

- cell efficiency
- the reduction in pure silicon used due to ribbon processes and advanced slicing
- use of automation
- large area continuous processing in the amorphous silicon area.

The results of Maycock's price analysis, which in turn is based on the Jet Propulsion Labs' assumptions and software, are shown in **Exhibits 2 and 3**.[4] Exhibit 2 indicates that concentrators and amorphous silicon modules will remain the most cost competitive through to the year 2000, with an average price of $1.66/Watt peak (1987 U.S. dollars). In the year 2000, the silicon ribbon sheet costs, which depend on production quantities, will still be higher compared to amorphous silicon, concentrators, and poly-crystalline silicon modules. The single crystal module costs are expected to be identical to those of ribbon sheet modules in the year 2000.

On the average, based on price trends for various module types, Maycock expects the price, in constant 1987 U.S.[5] $/Wp, to decline from $5.50 in 1987 to $3.50 in 1990, to $2.50 in 1995 and to $2.00 in 2000. Exhibit 3 indicates that the installed costs of PV systems differ depending on the type of system. The remote systems (IkW), generally used at telecommunications relay sites, portable water pumping, cathodic protection, irrigation, refrigeration and desalination, have higher installed costs than the large systems (1-10 MW) used in central power. Maycock indicates that remote site system costs will drop from $10.80/Wp in 1987 to $4.05/Wp in the year 2000. This forecast is generally similar to the pessimistic projections of systems prices provided by Commission of the European Economic Community in 1982 and Polydyne Inc.,[6] at the EEC conference.

4 Paul D. Maycock, **Photovoltaic Technology, Performance, Cost and Market Forecast to 2000**, 1988.

5 Wp indicates peak watts.

6 From appendices to Maycock's report.

The overall trends in the photovoltaic industry suggest a strong market in the future.[7,8] The 1988 production capacity of the 9 major manufacturers of amorphous silicon in the worldwide market ranges from 15-18 MW and is expected to reach 43-50 MW by 1990. These major manufacturers (Arco, Sanyo, Fuji, Chronar, Solarex, Sovonics, Glasstech Solar, Kaneka and Taiyo Yuden) are fully aware of the fact that for significant market penetration to occur, amorphous silicon modules must become more efficient, more reliable and more cost-effective ($3 per Watt or less).

It is encouraging to note from the literature that progress towards a stronger PV industry has occurred despite some depressing trends in the economic and political environment such as declining oil prices, oversupply of natural gas in the U.S., and failure of the U.S. congress to extend tax credits for solar energy.

The market forecasts developed by Maycock appear to provide a realistic range under two scenarios. The first , called the "Business as Usual" scenario, makes several status quo assumptions. For example, oil prices remain in the $12-22 per barrel range, the policies of governments do not change, fewer, if any, tax credits are available and there is no serious oil shortage. The "accelerated" market scenario assumes escalating oil prices at 2-3 percent per annum, a new administration in the U.S. with a long-term energy strategy, and a greater concern for environmental pollution and safety.

The projections made under both these scenarios are more conservative, and appear far more reasonable, than forecasts made by other authors in the early and mid 1980's. The Maycock study also seems to have more validity because it takes into account the forecasts of most authors and government agencies, and sometimes explains the reasons for differing from these forecasts.

This review draws heavily from Maycock for market forecasts by technology. The market trends in each market sector by application are, however, drawn from a variety of sources. The projections for the different market segments described below are summarized in **Exhibit 4**.

7 M.J. Blanco, op.cited.

8 Post, H.N. and Thomas, M.G., "Photovoltaics Systems for Current and Future Applications", **Solar Energy**, Vol. 41, No. 5, pp-465-473, 1988.

Consumer Products

This market sector has a variety of applications in consumer electronics, watches, calculators, radios, LCD display, clocks, thermostats, etc. Some higher power applications include rechargeable tools, drills, weed eaters and clippers. In this market the price elasticity of demand is very high. Based on the technology forecasts and the price of silicon modules, some manufacturers like Sanyo project the market demand to be 60-80 MWp for such applications, by the year 2000.

The Central PV Generation Market

Growth in this market sector did not meet the expectations of various earlier forecasts. Several major projects and production plants were cancelled in the U.S., e.g., the SMUD (Sacramento Municipal Utility District) project, and the Solarex and Intersol plants. It appears that cost reduction and high volume sales are necessary for PV to grow significantly in this sector. Also, tax credits for "third party financing" seem to be a very important prerequisite for growth.

The economics of central PV in 1988 is analyzed by Maycock who gives the following cost summary based on extensive research:

- installed system cost - $7.00/W
- system warranty 5 years, 90% performance at 2500 Wh/year
- annual AC Electricity per peak Watt - 2200-2600 Wh/W of capacity
- annual value of electricity $.25
- O&M cost per Watt/year - $.02
- system life 20 years.

Given the above , an investment of $7 per watt yields $.25 per year worth of electricity and is, therefore, not economically viable for base loads. Unless installed system costs drop to $2.50 per watt, such a PV application will not be attractive. However, some growth could be achieved by penetrating those utilities which still burn oil for peaking and intermediate electricity. Some forecasts suggest 100 MW/year PV sales from this strategy.

The U.S. Department of Energy (DoE) plan of 1986 assumes lower costs in its projections for central station PV. Based on the dependence on oil, gas and nuclear generation, five U.S. states offer the best target opportunities for PV. These five are California, Florida, Hawaii, Arizona and New Mexico which, collectively, form the U.S. sunbelt market.

Based on the projected economic situation, government incentives, and current factors in specific markets in the U.S., the central station PV market is expected to reach 10 MW under the "business as usual" scenario (no oil price escalation, not many tax credits) and 100 MW under the accelerated scenario (oil prices escalate, government supports PV) in the year 2000. The accelerated scenario is not very likely to occur (with less than a 30 percent chance according to Maycock).

Off-the-Grid Residential and Rural Markets

The off-the-grid-residential market sector appears promising in the U.S. and has expectations to serve 1 million houses without electricity, 3 million motor homes, 2 million live-in boats and house boats and 20 million campers. The U.S. market appears critical for the world market. At a price of $2/Watt by the year 2000, the market in U.S. will reach a size of 20 to 40 MW.

The off-the-grid international market is primarily rural. The market has been strong in Spain, Southern France, Italy and Scandinavian countries. Village community centers are becoming quite popular. India has a large projected market for off-the-grid rural PV. There is a solid market, though limited in size, for small off-the-grid stand-alone systems for lighting, entertainment and refrigeration[9]. This market would grow at higher rates if more information on PV systems is made available to potential customers. However, current profit margins cannot sustain higher marketing costs. On the other hand, if governments encourage this market through R&D and financing, PV systems could penetrate the segment at higher than expected rates.

The world market for off-the-grid rural PV could be 15 to 40 MW by the year 2000. A large number of international markets are likely to assume local assembly and partial production responsibilities within this time frame.

Grid Connected Residential Market

The economics in this market sector are complicated. The U.S. is the largest user of this technology. The DoE supported about 30 experiments in

9 Post, H.N. and Thomas, M.G., op-cited.

grid connected houses. The experiments demonstrate that PV systems can perform as designed, although mounting schemes need improvement to keep the cells cool. The experiments also indicate that there are no code barriers to PV systems, financing will be available, and that PV systems could be insured. However, unless installed costs go down to $2-3 per W, this market will not take off. At these price levels, 5 to 20 MW of PV is likely in this market segment by the year 2000.

Communication/Signal Market

This market sector has significant worldwide potential. PV applications for powering microwave repeaters, TV translators, radio telephones, educational TV, mobile radios, remote signalling, and telemetry have proven to be reliable and economic.

The U.S. and other international markets look promising for the PV communications sector. Saudi Arabia, Egypt and Kuwait have used PV for communications. Latin American users have implemented PV for establishing communication links with villages. Venezuela and Ecuador will follow suit. In Asia, large potential exists in India, Pakistan, Thailand and Indonesia. In Africa, the Post and Telegraph of South Africa has used PV. If the African economy improves, there will be more demand for communications-related PV applications. Tanzania, Kenya, Nigeria and Sudan show promise as PV markets for telecommunication applications.

The overall communications market is forecast at 40 to 60 MW in the year 2000. This forecast appears to be very achievable.

As reported by Photovoltaic Insiders' Report, a recent Frost and Sullivan study (1987) has forecast the rural electrification, cathodic protection, telecommunications and related remote site markets to be in the order of 73 MW by the year 1992[10]

PV/Diesel Hybrid Market

The diesel or gasoline generator can be used as the storage for a PV system. The world diesel market is primarily in the Middle East for applications such as water pumping, provision of electricity for small houses, community centers, etc. This market segment overlaps with the off-the-grid rural market segment. The replacement market is further segmented by the size of diesel engines, e.g.,

10 This report on remote site power markets was not purchased since other reports were known to refer to its key projections.

5 KW and under, 6 to 20 KW and between 21 and 100 KW. With a projected module price of $2.50/W and a system price of $4-5/W, the market demand in this sector in 1990 is projected at 40 to 100 MW. The wide range is used to cover uncertainties in the worldwide economies.

Relative Strengths of Various Markets

A report entitled "Photovoltaic Export Trade of the USA" (Solar Trade International) provides data on U.S. exports to the world. The reports (1985-1987) are useful in that they indicate the trends in the U.S. export trade. From the relative level of U.S. exports to the various markets, it appears that Europe and the Far East continue to offer significant opportunities. South Asia and the Caribbean markets are also reported as showing significant growth. **Exhibit 5** summarizes the U.S. export trade in PV to various countries for the years 1984 to 1987.

Market Trends Summary

The above examination of worldwide markets for the various sectors captures the key trends described in the literature. The forecast numbers from Maycock are used because they best describe the impact of the "status quo" scenario and the "accelerated scenario". Secondly, case studies and extensive cost analyses support these forecasts. These include the Frost and Sullivan reports (1981 and 1985), which we reviewed to compare the various forecasts. In our opinion, Maycock's forecasts fall within an acceptable range and provide a reasonable profile for the worldwide market demand for PV. This view is consistent with some EEC projections and the economics reflected in U.S. Department of Energy publications.

Public Sector Policy Trends

The public sector is a major player in the photovoltaic power system market. Governments in Canada, Japan, Europe and the U.S. have assisted in promoting the photovoltaic industry. The main initiatives taken by these governments in the past are summarized below. Also, a brief discussion of the key areas for future government involvement is provided.

Canada

In the Canadian PV market, the public sector, and the federal government in particular, is involved in a variety of ways,[11] for example:

- In the years 1982-1984, the government stimulated demand by using at least 40% of photovoltaic power generated.
- The government also provided significant support for Research and Development activities.
- Import duties have been exempted on some photovoltaic modules for end-uses such as navigational aids.

Despite this involvement in the past, the Ontario Ministry Report states that a more strategic approach to photovoltaics is necessary. The overall objectives of an Energy Program should be translated into sub-objectives for various renewable energy forms and, in this context, the role of photovoltaics should be studied. Since PV research requires a significant amount of resources before any breakthrough is accomplished, the government should make a decision on the level of effort it can afford for PV R&D and, secondly, should examine the sufficiency of this level of effort for specific initiatives. A cost-benefit framework would help to identify the most cost-effective areas for government-funded R&D. Through a strategic approach, the government can examine the relative worth of various promising market segments, such as remote site power, off-the-grid rural applications, and diesel replacement.

Japan

The Sunshine Project of Japan has been widely discussed in literature.[12] Recent reports suggest that the Japanese government continues to actively support PV initiatives. The "New Energy Foundation", established under the Sunshine Project, supports investigations of new energy technologies, case studies for economic feasibility, market research, and international cooperative alliances. One of the most important concepts introduced under the program is amorphous silicon solar cell production using an automated assembly line. The program has also fostered a wide variety of application systems developed especially for consumer electronics applications.

11 Ontario Ministry of Energy, **Assessment of the Canadian Market for Photovoltaic Power Systems**, 1984.

12 U.S. Department of Energy, **Abstracts, National Photovoltaics Program Annual Review Meeting**, 1984.

Europe

The photovoltaic power generation program in Europe[13] covers the period 1985-1989. The overall EEC program budget is reported at 20 million ECU. The three major areas of R&D under this program are:

- amorphous silicon solar cells
- thin film solar cells from alternative materials
- photovoltaic pilot program.

This program is somewhat different and less ambitious compared to the earlier (1979-1983) Solar Energy R&D program.[14] The European program also focuses on international alliances, e.g., agreements between Arco Solar and Siemens to start a major amorphous silicon manufacturing facility in Europe. In addition to amorphous silicon, innovations in the thick crystal area are also an interesting development in Europe. The Japanese success in polycrystal ingot technology will be tried by the Wacker/Kyocera joint venture.

U.S.A.

The U.S. public sector policy toward photovoltaics has been subject to change depending on the administration in power. For example, under the Carter Administration, U.S. government R&D funding stimulated the PV industry's sales.[15] President Reagan's shift to use of market forces, together with generous tax credits, led to the construction of larger plants with good economies of scale. In 1985 government funding became scarce. Despite this, the industry self-funded its R&D in the order of $50 to $75 million dollars and demonstrated that without government leadership it could still sustain its progress. The current millieu, as reported by Maycock, is one of no tax credits from the Central Administration and the disappearance in many states of support for PV. Even in this scenario (business as usual), the U.S. PV industry looks quite strong. As seen by Post and Thomas (from Sandia National Laboratories), standalone applications for telecommunications, vaccine refrigeration, water pumping, etc., are economically viable and technologically reliable. The central power applications, however, do not appear economically viable in the short run.

13 Commission of the European Communities, **Photovoltaic Power Generation R&D Programme**, August 1987.

14 U.S. Department of Energy, Abstracts, op-cited.

15 Frost & Sullivan Inc., **Photovoltaic Market in the U.S.**, July 1985.

EXHIBIT 1

TECHNOLOGIES APPLIED BY MANUFACTURERS IN THE U.S.

Technology	Manufacturer
Single Crystal	Arco Solar Silicon Sensor Solec Int'l Tideland
Poly-Crystal	Solarex
Amorphous Silicon	Arco Solar Chronar Solorex Sovonics
Concentrator	Entech Intersol
Dendritic Ribbon EFG Ribbon	Westinghouse Mobil Solar

SOURCE: M.J. Blanco, **Photovoltaic Export Trade of the U.S.A.**, Solar Trade International, 1987.

EXHIBIT 2

ACTUAL AND PROJECTED

AVERAGE PRICE OF SILICON-BASED OPTIONS

(Constant 1987 U.S. Dollars Per Peak Watts)

Modules/ Silicon Options	1987 Price ($/Wp)	1990 Price ($/Wp)	1995 Price ($/Wp)	2000 Price ($/Wp)
A. Ribbon (Sheet)	7.50	5.00	3.50	3.33
B. Single Crystal	5.40	4.0	3.50	2.50
C. Polycrystal	5.40	3.50	3.00	3.33
D. Concentrators	5.00	3.00	2.00	1.66
E. Amorphous Silicon	5.00	2.50	2.00	1.66
Average ($/Wp)	5.50	3.50	2.50	2.00

SOURCE: Paul D. Maycock, **Photovoltaic Technology, Performance, Cost and Market Forecast to 2000**, 1988.

EXHIBIT 3

COMPARISON OF REMOTE SYSTEM (1KW) AND LARGE SYSTEM (1-10 MW)

INSTALLED COSTS PER KWp AND WP

(Constant 1987 U.S. Dollars)

	1987		1990		1995		2000	
	Remote	**Large**	**Remote**	**Large**	**Remote**	**Large**	**Remote**	**Large**
Module	7,000	5,000	5,000	4,000	3,000	2,000	2,000	1,500
Battery	2,000	500	1,500	400	1,500	200	1,500	150
Wiring	100	500	50	300	50	200	50	150
Labour	1,500	1,000	1,000	800	800	500	500	300
Total $/KWp	10,600	7,000	7,550	5,500	5,350	2,900	4,050	2,100
Total $/Wp	10.60	7.00	7.55	5.50	5.35	2.90	4.05	2.10

SOURCE: Paul D. Maycock, **Photovoltaic Technology, Performance, Cost and Market Forecast to 2000**, 1988.

EXHIBIT 4

WORLDWIDE MARKET FORECASTS

FOR PV MODULES IN MWp

"BUSINESS AS USUAL" SCENARIO[I] VS. "ACCELERATED SCENARIO" (II)

Sectors	1984		1985		1987		1990		1995		2000	
	I	II	I	II	I	II	I	II	I	II	I	II
Central Station	2	2	2	2	.5	.6	4	4	5	10	10	100
Consumer Products	6	6	7	7	10	10	30	40	50	70	60	80
Off-the-Grid Residential	2	2	2	2	2	2	4	8	10	20	20	40
Off-the-Grid Rural	3	3	3	3	4	4	6	4	8	15	20	40
Grid Connected Residential	.1	.1	.1	.1	.1	.3	.5	1	1	5	5	20
Communications	6	6	8	8	10	10	20	20	30	40	40	60
PV/Diesel Commercial	3	3	4	4	5	5	5	10	20	50	40	100
Total (MWp)	22	22	26	26	32	32	70	87	124	210	195	440
Price ($/Wp)*	7		6.50		5.50		4		3		2	

I - "**Business as Usual**" or status quo scenario assumes no change in oil prices and that tax credits are not available.

II - "**Accelerated Scenario**" assumes escalating oil prices and long-term energy strategy in the public sector.

* Dollars are 1988 U.S. dollars

SOURCE: Paul D. Maycock, **Photovoltaic Technology, Performance, Cost and Market Forecast to 2000,** 1988.

EXHIBIT 5

DISTRIBUTION OF U.S. TOTAL PHOTOVOLTAIC EXPORT SHIPMENTS BY WORLD REGIONS

Region	1984 % Total Exports	1985 % Total Exports	1986 % Total Exports	1987 % Total Exports
Europe	40.9	46.9	30.9	40.2
Far East	17.8	16.7	23.2	20.6
Oceania	4.3	8.3	3.7	7.5
Africa	9.7	7.1	9.8	8.2
Middle East	5.7	6.8	5.6	6.7
North America	5.1	5.9	11.0	5.1
South East Asia	9.1	5.5	5.6	5.8
South America	4.5	2.0	7.9	3.9
South Asia	0.7	0.5	1.4	1.0
Carribean	2.3	0.4	0.8	1.0
Total %	100.0%	100.0%	100.0%	100.0%
Total Exports	2.3 MW	2.9 MW	3.2 MW	3.8 MW
Average Prices (Cells)	$6/Watt	$5/Watt	$4/Watt	$3/Watt
Average Prices (Modules)	$8/Watt	$7/Watt	$6/Watt	$5/Watt

SOURCE: M. J. Blanco, **Photovoltaic Export Trade of the U.S.A.**, Solar Trade International, 1985, 1986 and 1987.

Appendix A

List of Key Literature Contributing to the Literature Review Summary

1. M.J. Blanco, Photovoltaic Export Trade of the U.S.A., 1987.

2. Commission of the European Communities, Photovoltaic Power Generation R&D Programme, August 1987.

3 Frost and Sullivan, Photovoltaic Market in the U.S., July 1985.

4. Frost and Sullivan, World-Wide Photovoltaic Power Systems, Market Opportunities, 1981.

5. Frost and Sullivan, World-Wide Remote Site Power Systems, 1987.

6. Paul D. Maycock, Photovoltaic Technology, Performance, Cost and Market Forecast to 2000, 1988.

7. Ontario Ministry of Energy, Assessment of the Canadian Market for Photovoltaic Power Systems, 1984.

8. Post, H.N. and Thomas, M.G., "Photovoltaics Systems for Current and Future Applications", Solar Energy, Vol. 41, No. 5, pp-465-473, 1988.

9. U.S. Department of Energy, Abstracts, National Photovoltaics Program Annual Review Meeting, 1984.

Appendix B

Provisional

List of Photovoltaics Market Literature (Chronological Order)

Title: Photovoltaic Power Systems Market Identification and Analysis, **Author:** B.D.M. Corporation, **Publisher:** U.S. Department of Energy, 1978

Title: Photovoltaic Venture Analysis, **Author:** Costello, Dennis; Posner, David, **Publisher:** Solar Energy Research Institute, July 1978

Title: Photovoltaic Markets: A Review and Assessment, **Author:** Posner, David M., **Publisher:** 1979.

Title: Near-Term Markets for Photovoltaic Power Systems in Canada, **Author:** Haas, Lawrence J.M., **Publisher:** Ottawa: National Research council Canada, 1980.

Title: Photovoltaic Commercialization: An analysis of Legal Issues Affecting a Government-Accelerated Solar Industry, **Author:** Lamm, David, **Publisher:** Springfield, VA.: NTIS, 1980.

Title: International Market Assessment of Stand-Alone Photovoltaic Power Systems for Cottage Industry Applications, **Author:** Philippi, Therese M., **Publisher:** Springfield, VA.: National Technical Information Service, 1981.

Title: Photovoltaic Product Directory and Buyers Guide: (June 1981), **Author:** Watts, R.L.; Smith, S.A.; Mazzucchi, R.P., **Publisher:** Springfield, VA.: NTIS, 1981.

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